Moving Geothermal Sites from Exploration Prospects to Economic Project

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California Geothermal Summit
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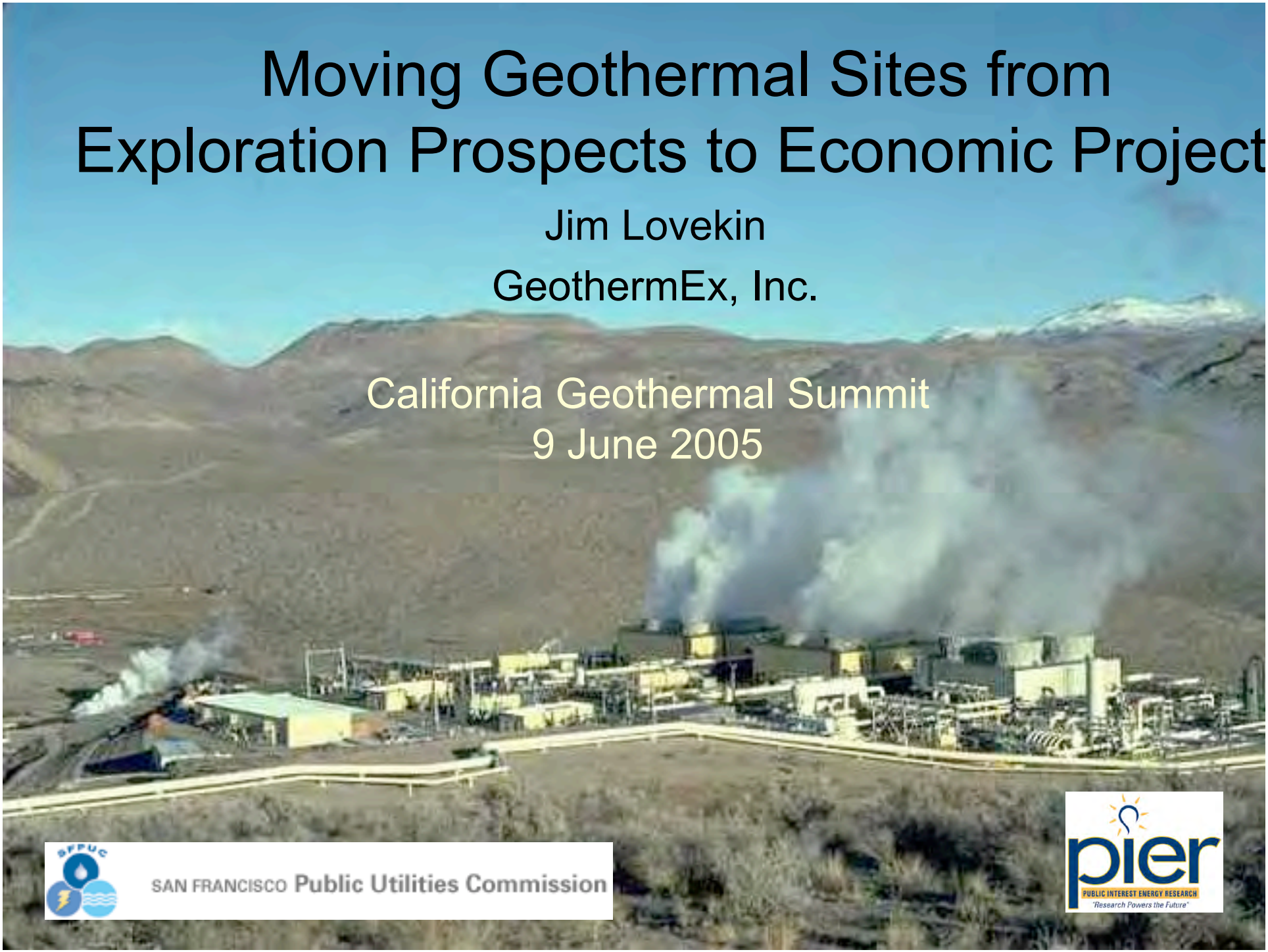

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OUTLINE

- Semantics of Resource Assessment
  - Resources
  - Reserves
  - Generation Capacity
- Rankings of Projects
- An Example: CEC-PIER Assessment
  - Methodology
  - Data Needed
  - Probabilistic Approach

SEMANTICS

- Resource
  - Thermal energy in the ground
  - Subset is shallow enough to be accessible
  - Further subset is concentrated enough to be useful
- Reserve
  - Portion of useful, accessible resource that is economic
  - Also used (somewhat loosely) to describe thermal energy that could become economic for development
  - Caveats: productivity, market, and development cost
- Generation Capacity (Electrical Energy)

RANKINGS

- Maturity
- Generation Capacity (MW)
- Cost

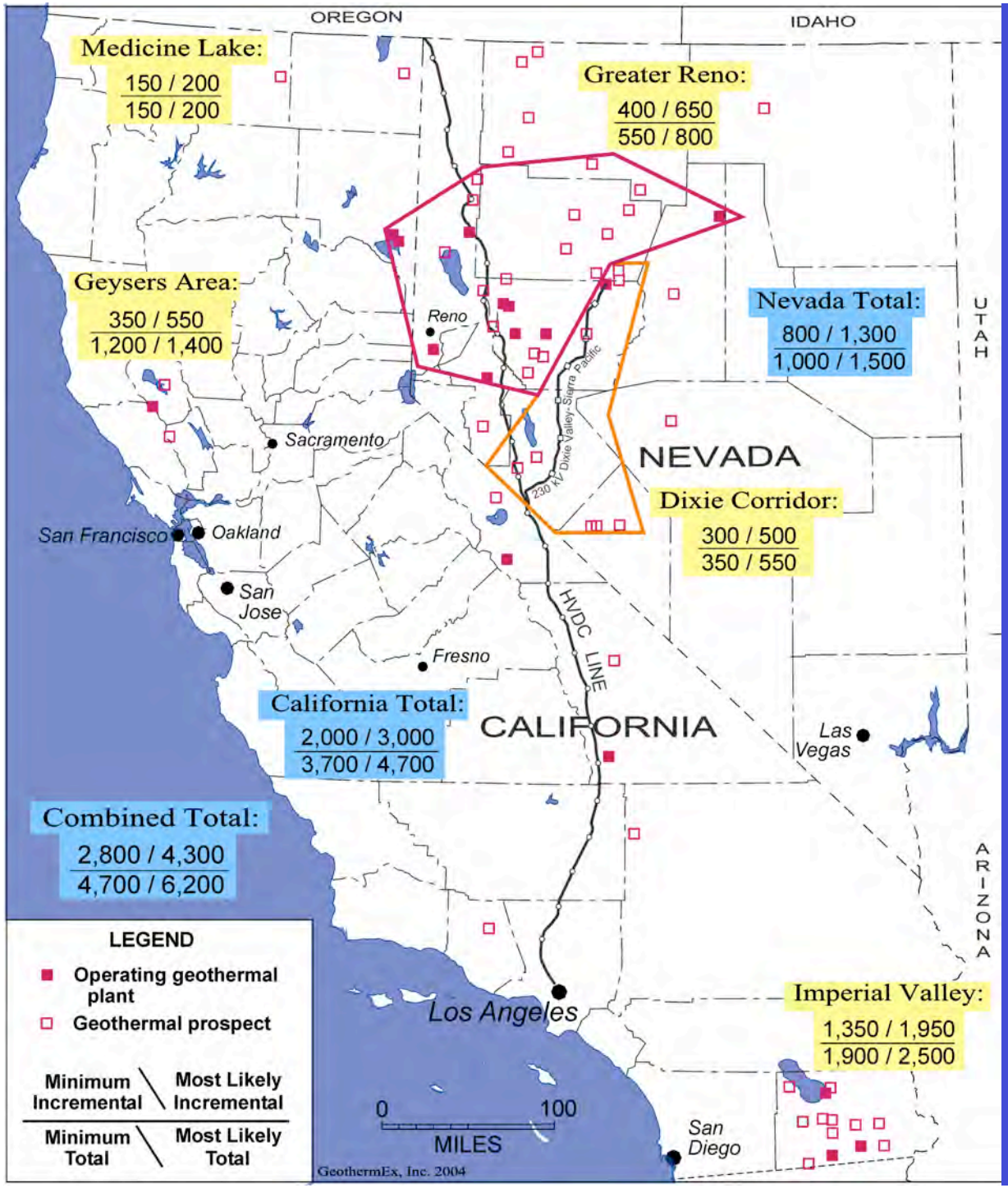
PROJECT MATURITY

- Challenge is to objectively assess and compare resources at different stages of development

RANKING BY MATURITY

Exploration – Development Categories:

- Existing power plant is operating
- No operating plant, but at least 1 well with tested capacity of 1 MW or more
- No well tested at 1 MW or more, but downhole temperature of at least 212°F
- Not meeting A, B, or C: resource properties from other sources (geology, geochemistry, geophysics)



RANKING BY MW

CEC-PIER Assessment (2004): Generation Capacities of Major Geothermal Resource Areas in California and Nevada (Gross MW)

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GENERATION CAPACITIES

Area	Total Capacity		Capacity In Use	Incremental Capacity		Most-likely Incremental As % of State Total	Most-likely Incremental As % of Grand Total
	Minimum (Gross MW)	Most-likely (Gross MW)	(Gross MW)	Minimum (Gross MW)	Most-likely (Gross MW)		
California							
Imperial Valley	1,900	2,500	550	1,350	1,950	65%	45%
The Geysers	1,200	1,400	850	350	550	18%	13%
Medicine Lake	150	200	0	150	200	7%	5%
Other	450	600	300	150	300	10%	7%
California Total	**3,700**	**4,700**	**1,700**	**2,000**	**3,000**	**100%**	**70%**
Nevada							
Greater Reno	550	800	150	400	650	50%	15%
Dixie Corridor	350	550	50	300	500	38%	12%
Other	100	150	0	100	150	12%	3%
Nevada Total	**1,000**	**1,500**	**200**	**800**	**1,300**	**100%**	**30%**
Grand Total	**4,700**	**6,200**	**1,900**	**2,800**	**4,300**	-	**100%**

Values rounded to increments of 50 MW

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METHODOLOGY TO ESTIMATE GENERATION CAPACITY

- Reservoir properties
  - Average temperature
  - Depth to top
  - Thickness
  - Area
  - Porosity
- Other factors
  - Recovery factor (0.05 to 0.20)
  - Heat capacity of rock (39 BTU/ft^3 °F)
  - Utilization factor (45%)
  - Capacity factor (90%)
  - Plant life (30 years)

PROBABILISTIC APPROACH

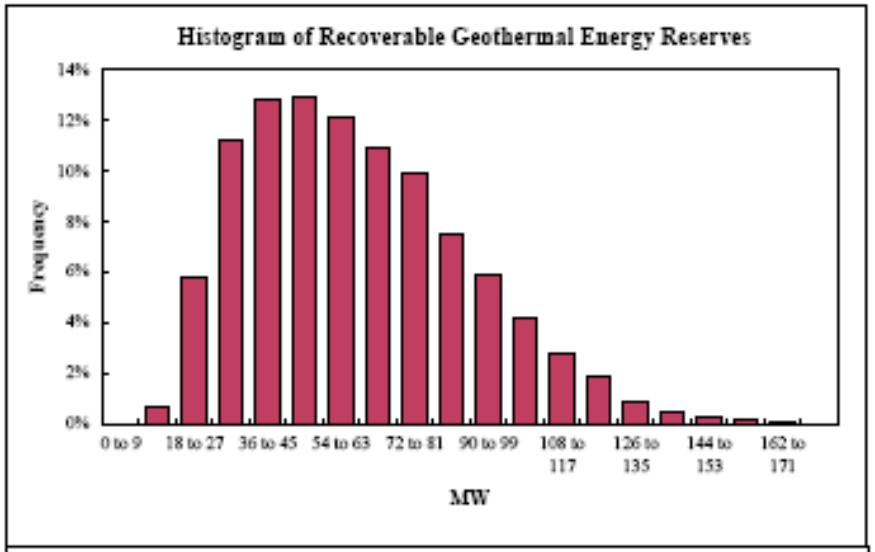
SUMMARY OF INPUT PARAMETERS

Variable Parameters	Minimum	Most Likely	Maximum
Reservoir Area (sq. mi.)	1.7	3.4	5.1
Reservoir Thickness (ft)	2500	3500	4500
Rock Porosity	0.03		0.07
Reservoir Temperature (°F)	340		380
Recovery Factor	0.05		0.20

Fixed Parameters		
Rock Volumetric Heat Capacity	39.0	BTU/cu. ft°F
Rejection Temperature	50	°F
Utilization Factor	0.45	
Plant Capacity Factor	0.90	
Power Plant Life	30	years

RESULTS

Statistics	MW	MW/sq. mi.	Recovery Efficiency
Mean	62.40	18.39	1.23%
Std. Deviation	26.82	6.84	0.43%
Minimum (90% prob.)	30.14	9.43	0.64%
Most-likely (Modal)	46.95	12.90	0.83%



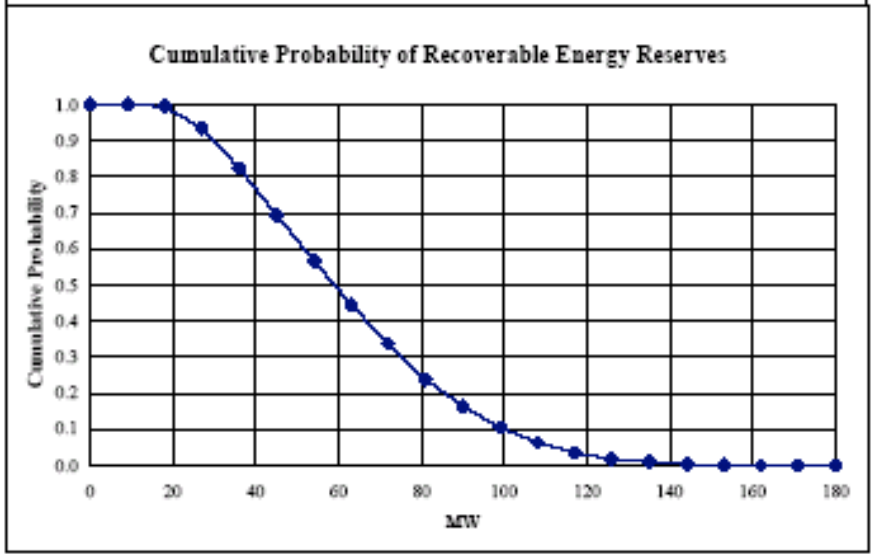


Figure FIS00-2:
Probabilistic Calculation of Geothermal Energy Reserves
FISH LAKE VALLEY, NEVADA

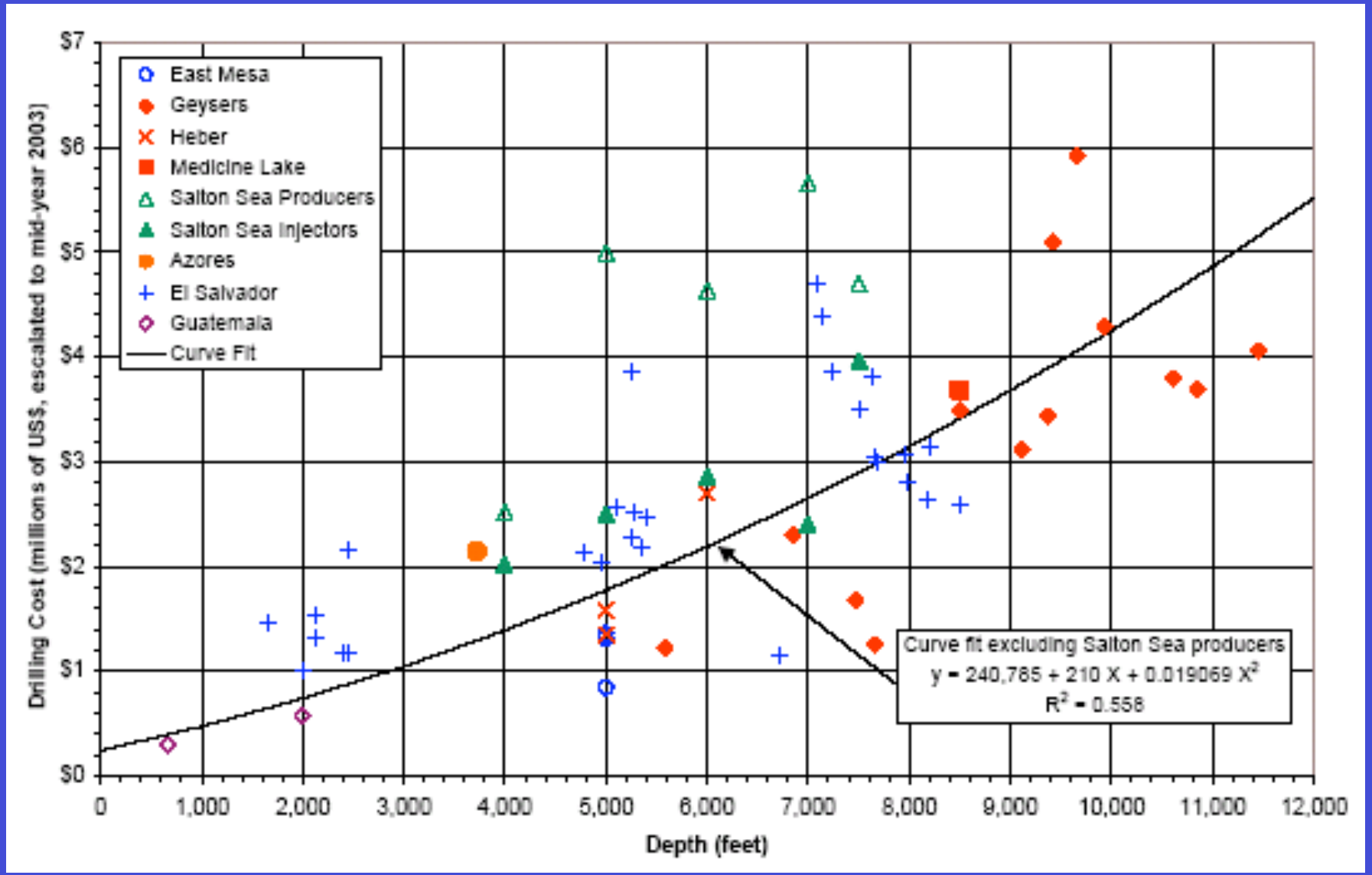
METHODOLOGY TO ESTIMATE CAPITAL COSTS

- Exploration
  - Up to drilling first full-diameter well
- Confirmation
  - Drilling until 25% of specified capacity is available at the wellhead
- Development
  - Drilling until 105% of specified capacity is available at the wellhead
  - Surface equipment at $1,500 / kW
  - Transmission-line interconnection

Exploration – Confirmation Costs

- Geology (field mapping)
- Geochemistry
- Geophysics
  - Gravity
  - Magnetics
  - Resistivity (e.g., TDEM, AMT, CSAMT)
- Intermediate-depth slim holes
- Full-sized confirmation wells (including testing)
  - Success rate 60% for confirmation wells
- Regulatory compliance
- Administration
- Resource assessment report

DRILLING COSTS



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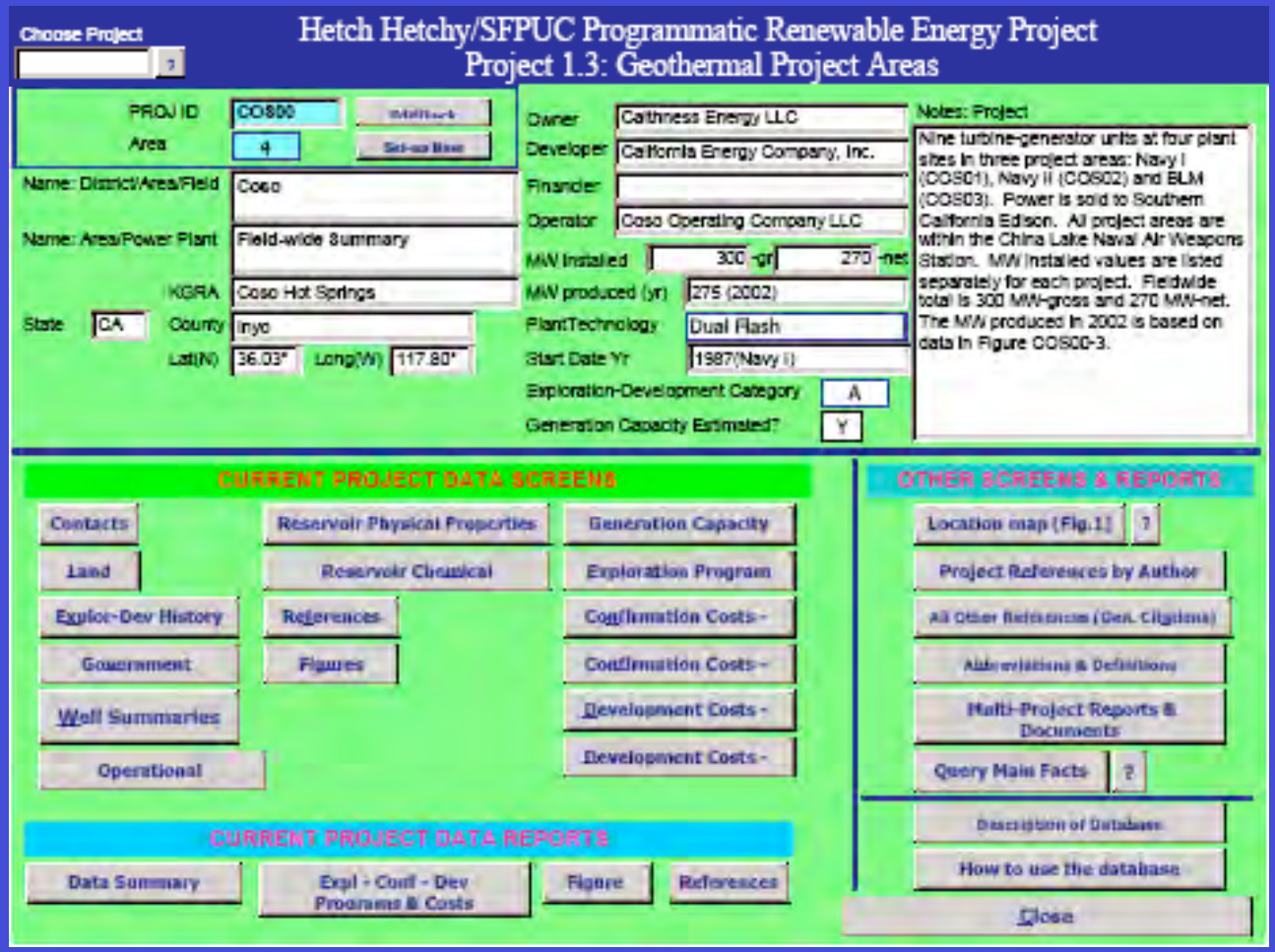
Development Costs

- Production and injection wells
  - Ratio of injectors to producers depends on technology used (e.g., flash or binary)
  - Success rate 80% for development wells
  - MW per well based on statistical correlation of MW vs. reservoir temperature
- Surface facilities on site: $1,500 / kW
  - Applied for all plant technologies (flash or binary)
- Transmission tie-in estimated in conjunction with separate analysis by another contractor for CEC-PIER Project

CAPITAL COSTS

- Costs in CEC-PIER Study as of December 2003
- Overall Average (64 projects): $3,100 / kW
  - Reflects all development costs (including transmission)
  - $2,950 / kW within California
  - $3,400 / kW in Greater Reno and Dixie Corridor
- Incremental geothermal capacity available:
  - 2,500 MW (gross) below average cost of $3,100 / kW
  - 2,000 MW (gross) within California below state average of $2,950 / kW
  - 1,700 MW (gross) below $2,400 / kW (assumed threshold to be competitive with other renewables)

PIER GEOTHERMAL DATABASE



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How to Get a Copy

- Full report and PIER Geothermal Database are available for free download at:
  - www.geothermex.com
  - On the Home Page, click on CEC-PIER Reports
  - Report is 264 pages (4.2 MB)
  - PIER Geothermal Database is 45.1 MB (zipped)

SUMMARY

- Geothermal resource assessment is a chicken-and-egg problem
  - Have to define a sufficiently large target to guide public policy (including transmission) and attract investment
  - At same time, have to avoid over-selling potential, to maintain credibility
- Probabilistic approach to assessing generation capacity allows some appreciation of both the risks and the potential rewards
- Ranking projects by costs (both initial capital and levelized life-cycle costs) shows where to focus development effort in near term